



# Necessity of Adopting Lean Techniques in Construction Projects

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## Abstract

The world has witnessed large growth of projects development during last two decades, where Dubai in the UAE has witnessed big increase in construction projects. Some of these projects are completed and delivered on time while others have not delivered on time, due to some challenges and uncertainties that caused delay which impacted work progress of some major activities. Lean construction and lean techniques have been introduced in the UAE construction projects, but it is not adopted as mechanism to complete and deliver projects on time. Lean techniques in construction projects can be introduced as a philosophy that reduce project duration through the elimination of waste in process during design and construction. The study aims to introduce principles of lean management in construction projects and the benefits of applications of lean techniques in projects through investigating the level of implementing lean techniques in some construction projects. Principles of underpinning lean methodology is also investigated, and part of the study was to find out benefits of lean techniques implications.

Principles of the study results revealed the necessity of adopting lean process and techniques in construction projects that can be implemented. Responsibilities of project team to use available tools to support implementation of lean to minimize the waste of project processes is identified in the results. Barriers and factors of preventing project team to adopt lean techniques are identified as a main result in this study. Major conclusion of the study identified the necessity of understanding the concept of lean techniques in construction to control the uncertainty and eliminate the waste that may occur during any process. It is also recommended that construction firms must adopt the lean techniques to improve the productivity by eliminating the wastes, including but not limited to benefits of implementing lean

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**Keywords:** Constructability, Lean techniques, Methodology, Productivity, Process

## 1. General Introduction

Lean in construction projects is introduced as tool to reduce project duration through the elimination of waste either in process or methodology. Waste is any work element/activity that is not adding value to the work progress can be eliminated. The main goal of lean implementation in construction projects is to reduce the project execution time. Lean transformation aims to create a lean & effective process, remove the process noise, create an agile process capable of adjusting rapidly to changing circumstances, ensure project team is thinking with a divisional hat and have improved communication between project team. Also, it reflects the commitment to create a culture for continuous improvement. Lean is defined by those who works in construction firms as a set of systematic management practices to improve efficiency and effectiveness by eliminating waste where values can be delivered with less waste during construction. Benefits of lean adoption in construction industry is making the team to focus on activities that has a value

which reduces the numbers of activities that cause a waste. Enhancing and improving productivity and work efficiency during project phases where staff and employees becomes more focused on delivering work values. Resource optimization and utilization will be a part of daily working process based on mechanism of waste elimination, reduction and work actual requirements. In addition, this technique is clearly streamlining the process that would deliver value to the client of the project where processes and activities without values can be minimized and eliminated. Work activities can be accelerated either during the design or construction based on removal of non-value activities after satisfaction of the client and project team. Project team including the work force will give more attention to the knowledge and innovation of lean implementation to create the required change that makes good value to the client requirements and needs. Many countries are started focusing on lean adoption based on analysis of work factors that lead them to eliminate the waste during design and construction mainly in design-build projects. The objective of the study is to present principles of lean management in construction industry and its benefits along with adopted tools based on feedback of developed questionnaire that is conducted during the research period. The conclusion of the research presented the necessity of understanding and adoption lean techniques in construction projects that can manage the uncertainty issues and can eliminate the waste that can happen during any of project life cycles where productivity can also be improved.

## 2. Literature Review

Lean principles of production have grown and were successfully implemented by Toyota Motor Company in Japan on forties of past century, The production system was considered by some to be the most efficient in the world, and it was claimed that their lean production principles could be applied not only to any other manufacturing process, but also to other business activities. These principles are being increasingly employed in many other commercial and industrial sectors. It can be categorized in terms of objectives, principles, and methods or tools. Lean has been judged to have improved construction project performance the world over due to its theoretical advantages and benefits. Leans has spread widely in manufacturing, moving far beyond the automobile sector where it originated and beyond the shop floor into white collar functions. Lean has also spread from manufacturing into product development, general services, aviation industry, ships and sub-marines' buildings, software development, health care delivery, and construction industry projects. The effective implementation of this concept in construction projects is rare in developing countries [1]. Adaptation of lean production concepts in the construction industry has been ongoing through fast development. Big, organized firms are becoming aware of benefits and outcomes of lean management in most kind of industries. The term "lean" is used consistently and is usually associated with lean manufacturing, lean thinking, lean production, and lean construction [2]. They further stated that lean practices were usually implemented based on some ideologies and scene that came up prior to the introduction of the lean concept. These ideologies include total quality management (TQM), as well as the just-in-time (JIT) production. The idea behind these ideologies [3] gave rise to the emergence of some of the key elements of lean which includes the focus on producing high quality products that are readily in need and relatively cost effective to users. This is based on proposals and discussions related to the improvement in quality and production. Lean construction according to [4] has of recent received audience as a way of improving construction performance and productivity. It has been presented to be the latest management concept that supporters for the minimization of waste in construction processes as well as changing the construction industry needs. Lean construction is a way of designing a production system that minimizes the waste of materials, time, and effort with a view to generating ample value within the construction process [5]. In general, Lean Construction projects are easier to manage, safer, completed sooner, cost less, and are of better quality.

Transformation and its management are a procedure of managing contracts and establishing quality and safety procedures which would ultimately lead to the increase in productivity and optimization of construction processes [6]. The senior managers and decision makers who works in big firms must focus on process review of contract management and requirements of their projects, so they can find out non added values of many activities which make them to eliminate the waste. Lean construction is a production management-based idea of delivering projects, the latest means of designing and building with a view to changing the previous ways of constructing [7]. So, senior managers must enhance communication process

to enable the team work to create and develop effective lean process after removing invaluable activities. The team can be encouraged to think, participate, and propose where possibilities of adjustments can be accomplished. Customer satisfaction and quality improvement are two main factors for evaluating the progress and reputation of organization, but it also depends on the clients, their requirements and needs, and the types and scale of projects undertaken as large companies are often engaged in mega projects whereas small firms concentrate more on small scale construction like housing [8]. Some of them success but others are failed because lean adoption processes are not entirely successful. Lean construction as a movement arose from recognizing limitations of current project management and applying new production management or “lean production” to the construction industry projects according to [9]. This is maintained because in construction lean can effectively minimize the direct cost and it helps in expediting work process where time, cost and quality can be maintained. In construction industry, purpose of project control is to minimize negative variance from cost and schedule. This view leads to contract compliance which relies on managing contracts. In effect, work must be pushed. By contrast, the focus of management in lean construction depends on production starting with workflow reliability and valuable capacity. Managing combined effects of dependence and variations is the first concerns in lean construction [10]

### **3. Leans construction tools and techniques in projects**

Lean construction can be introduced as a way of improving construction performance and productivity in project elements. It has been cited to be the latest management concept that supporters for the minimization of waste in construction processes as well as changing the construction industry needs. Lean construction is a methodology of developing system that minimizes the waste of materials, time and effort with a view to generating sufficient value within the construction process. Other than that performance of projects especially in construction will not be sufficient. Construction projects in the KSA normally have poor performance, which is mainly due to huge time and cost overruns [11]. Lean construction is a production management based idea of delivering projects on time, the latest means of designing and building with a view to changing the previous ways of constructing. In addition, massive environmental waste is also generated by the construction industry and the Saudi government issued a decree that requires all construction companies to meet new resource consumption standards to minimize the impact of waste in the construction industry [12]. All the various professionals in construction project can work together to enrich challenges experienced in a project. In applying the lean construction principles in construction projects, the process of design is carried out aim of achieving enhanced client satisfaction throughout the entire process. To address these challenges, lean construction has been introduced into the Saudi construction industry, and several contractors have realized the significance of implementing lean construction [13]. The lean construction concept is based on the Toyota Production System (TPS), which has been transformed into a newly systemized construction method all over the world. It aims to complete a project that meets customers’ requirements or client needs through waste reduction. Lean construction process is hinged on the following principles according to [14]:

- (a) Reducing waste
- (b) Specifying value from the perspective of the client.
- (c) Clearly streamline the process that would deliver value to the client
- (d) Minimize all non-value adding processes and activities
- (e) Ensure that the client agrees to halt and accelerate activities when the need arises.
- (f) Ensuring perfection is achieved via continuous improvement.
- (g) Ensuring that there is a flow between all value adding processes devoid of interruptions in managing the interfaces between the steps and activities

Most construction related activities have been presented to a complex process of delivering kind product via the incorporation of a temporary and multi skilled team. Further stated that the two main contributors to lean construction are Transformation Flow Value (TFV) and Last Planner System (LPS) which were later followed by Lean Project Delivery System (LPDS).

Transformation Flow Value (TFV): The introduction of the ideas of lean thinking into construction was formulated through the transformation-flow-value (TFV) theory of production. The TFV theory of production when properly deployed, could lead to improved performance in construction projects. They see construction production as a continuation of conversion flow processes of eliminating waste while the traditional method of construction dwells more on conversion only and ignoring flow and value.

Last Planner System (LPS): To achieve lean goals of reducing waste, increasing productivity, and decreasing unpredictability, mainly through a social process, by trying to make planning a mutual attempt and by increasing the reliability of the commitment of team members. In construction, LPS was a method that forms workflow and deals with project variability.

Lean Project Delivery system (LPDS): The Lean Project Delivery System (LPDS) according to [15] was one of the outcomes of the lean construction institute (LCI) that was developed from the manufacturing industry and later metamorphosed into the construction industry. LPDS is a conceptual framework developed for purposes of guiding the implementation of lean construction on project related production system.

The below eight factors can be considered as a part of lean construction techniques which are the backbone of LC and have evolved since its adoption in the construction industry. Lean construction techniques are procedures, structures, conceptions, models, methodologies, and products which when implemented assists corporations apply lean across the workplace. [16]

- Bottle Neck Analysis (BNA): It is a structured way of looking at the processes and workflows for developing a product or service. Bottleneck analysis is also used to address both present and future issues, by identifying and addressing operational and process challenges. Utilizing Lean practices to spot and rectify a bottleneck saves companies time, energy, and money.
- Master Pulling Schedule (MPS): It is the complete project schedule with milestones. MPS is prepared based on the design criteria and standards that supports the client's project targets which is influenced by breaking the project into smaller activities and showing their successive relationships. It does not describe the run of demands between tasks or activities beyond simple successive relationships
- Phase Schedule (PS): The PS is developed by the teams involved in each phase and it is more practical than the preliminary optimal schedule which is the master schedule. It is like scrum where activities can be divided on weekly basis. It must be prepared minimum of 4 weeks before the number one activity. MPS produces the Reverse Phase Scheduling (RPS) which is a tool that develops the schedule
- Weekly Worked Plan (WWP): It is generated according to scheduled meetings covers quality issues, safety issues, weekly schedule, needs of material needs, methods of construction, reserves of prepared work and any difficulty that can come up in the field. Therefore, it improves quality, safety, flow of work and material, performance, and the relationship among stakeholders.
- Value Stream Mapping (VSM): This tool establishes the current state of the construction process or supply chain to identify the wastes. The future state helps to develop improvement strategies. It is a technique developed from Lean manufacturing. Organizations use it to create a visual guide of all the components necessary to deliver a product or service with the goal of analyzing and optimizing the entire process.
- Total Quality Management (TQM): Most of the substantial tools used to address construction performance issues are based on the concept of plan-do-act. Functions involve identification and evaluation of the problem, developing, and implementing solutions, and evaluating and measuring the results.

- Increased visualization (IV): Communicating key information effectively to the workforce through posting various signs and labels around the construction site; workers can remember elements such as workflow, performance targets, and specific required actions if they repeatedly see them.
- Just in time (JIT): It is a management philosophy that calls to produce what the customer/client wants, when they want it, in the quantities requested, where they want it, without it being delayed in inventory. So instead of building large stocks of what you think the customer might want you only make exactly what the customer asks for when they ask for it. Resources can be controlled.
- First Run Study (FRS): First-run studies are utilized to remodel important tasks. Operations are scrutinized thoroughly, and ideas and suggestions are raised to explore alternative ways of doing the task. The PDCA (plan, do, check, and act) cycle is used to build up the first-run study.
- Integrating quality into production (IQP): It is a part of making the production team's responsibilities; reducing as much of waste, defects, and errors as possible. This could also include stopping production to resolve quality problems rather than jeopardizing reproduction for defectiveness

The supporters of lean construction are not very interested in the systemic implications of forever focusing on short-term efficiency. A joint public argument is that whereas the goals of lean construction and lean production may be similar, the approaches are different largely due to the project-based nature of construction, lean construction is a continuous process that applies throughout design, procurement, manufacture and construction. It is an 'integrated process' in which clients, designers, contractors, and suppliers must be committed to working together. This leads to a major improvement in the cost saving and quality. Lean construction also minimizes the direct cost of effective project delivery management and assists project managers in making informed project decisions at all levels of the project. Lean construction promotes continuous improvement by encouraging reflection on lessons learned to eliminate the waste [17]. Lean construction is reported to lead to increased quality and productivity in the construction industry. Lean construction involves ways of designing production systems to minimize waste in materials, time, and human effort, with the aim of generating maximum cost-effective value [18]. Some of the theoretical and supposed principles behind lean construction are already founded and considered as a main supports factor for sustainable lean construction in the industry as explained and summarized in the general introduction and literature review, the factors are but not limited to the following:-

1. Eliminating waste and errors.
2. Direct and immediate involvement that lead to change.
3. Improving communication plans.
4. Improving work planning and forward scheduling.
5. Specifying value from the perspective of the customer.
6. Identifying the processes that deliver customer value (the value stream).
7. Eliminating activities that do not add value.
8. Increased visualization

#### **4. Research Methodology**

Comprehensive research method is adopted during the study where information of literature review is considered as a major data supported development of questionnaires. Projects Managers of big construction projects are requested to respond to the questionnaire to collect précised data related to necessity of adopting lean methodology, benefits, its construction and its tools. Primary data is generated based on the combination of finding the analysis of literature review and other different sources that has been approached through meetings, interviews and questionnaires.

### 4.1 Research Approach

Two approaches of data collection, qualitative and quantitative analysis has been approached to help the author developing proper analysis of the collected data through a detailed methodology.

### 4.2 Quantitative and qualitative analysis

Quantitative analysis is the assessment of data collected by means of survey techniques through statistical methods with the purpose of ensuring that the collected data are both reliable.

### 4.3 Data Collection

Primary and secondary data is the main types of data that has been collected by the researcher with the intention of developing the expected results. Collected data has been dealt with in turn in order to explain its necessity for this research.

## 5. Design of Questionnaires

A critical evaluation of the application of lean principles and techniques will help a creating a possibility and chance for value-adding and waste reduction in construction industry. The objective of this research is to identify the barriers to the adoption of lean in construction projects, and to find out if principles are adopted by project managers and rest of project team members. This study selected the quantitative research method to determine the benefits of adopting lean construction techniques in UAE by using primary and secondary data. Questionnaire surveys based on literature review are one of the methods to gather information/data. Questionnaires are developed to collect the required information and data for introducing principles of lean management in construction projects and the benefits of applications of lean techniques in construction as well, it is based on explanations of barriers of lean applications by project team. One hundred project managers of five big organizations specialized and serves in construction requested to respond to questions identified in table 1 that are related to tools of lean construction.

Key factors related to the adoption of lean construction and applications are listed in table 1, where the survey is prepared to evaluate the perceptions of project managers to the level of understanding and adoption applications of lean guidelines in their projects. The questionnaire is developed based on eight important factors/key areas that have been identified in the literature review and background of that study. Based on the feedback of participants, the level of meaning of each area has been identified as recorded in table 1. Major identified key areas are, related to waste elimination, communication, added value, scheduling and planning, risk identification, visualization, and stakeholders' needs.

Table 1. Key factors and tools of lean construction

S N	Questions and factors related to principles of tools and techniques of lean construction in projects	Validity	Means	Rendering	Standard deviation
1	Do you review the process to <b>eliminate waste</b> and error?	100	2.91	56 %	1.610
2	Are you involved during <b>design &amp; built review process</b> ?	100	3.12	61 %	2.102
3	How do you monitor administration of <b>project materials</b> ?	100	3.62	64%	2.511
4	How do you improve <b>planning and scheduling</b> of lean?	100	3.89	67%	2.663
5	Do you discuss the <b>awaited added-value</b> with the client?	100	3.99	69%	2.799
6	How do you evaluate the <b>productivity</b> during the review?	100	4.01	71%	2.861
7	Do you prepare team <b>communication plan</b> of lean?	100	4.29	73%	2.992
8	Do you encourage to have BIM or any <b>visualized system</b> ?	100	4.51	75%	3.012

## 6. Results and Discussions

### 6.1 Data Analysis and Findings

According to the analyzed data, it is observed that 67% of respondents are willing to practice lean tools and techniques during the life cycle of the projects they are managing. They do believe in lean tools and they are satisfied about its benefits in projects. The implementation of lean construction concepts increase the quality and productivity of construction projects [19]. 33% of respondents confirmed they are willing to practice lean, but they need to learn about it and understand its principles.

Regarding the first factor, eliminating the waste, 56% confirmed that they review the process during preparing construction methodology of each main activity, a lot of actions can be eliminated, while 44% of respondents they do not review due to some reasons such as knowledge, time constraints, and level of experience in lean tools. For second factor design and built review process 61% confirmed that they must review the process of work activities due to the nature of contract type where outcomes of design submittal must be very cost-effective design. 39% of others leave it to the design managers to review process of design management Regarding the third factor that is the project materials administration, 64 % of respondents confirmed that procurement process can be administered efficiently if process are reviewed based on value added consideration e.g. conditions of procurement, alternative materials, submittals and approval, etc. other 36% stated that they focus on approval process and issue of purchase order to bring the materials to the site without delay.

Forth factor, planning and scheduling, 67% confirmed that they review activities of each mile stone by focusing on the work process of each activity and resources required, while 33% stated that they work according to the planned schedule to achieve the mile stone without any delay. The awaited added-value that is fifth factor, 69% of correspondents confirmed that they focus on the added value of the client for the proposed project and they try to comply with the required efficient need of the project that will add the real value for the project, the remaining 31% of respondents stated that there duty is to complete the project according to the design criteria, drawings, specifications without any changes and they are not interested in changes during the design and construction. Lean Construction is a “way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value [20]. Factors number 6, it is about productivity of the team in the project, 71% of respondents confirmed that they monitor the productivity of the resources and they mentor the resources to accomplish the desired productivity to avoid any waste during the work. 29% stated that they increase the resources to accomplish the deadline of any activity without looking to reasons that cause low productivity. Regarding factor number 7 which is the communication plan, 73% of respondents confirmed about necessity of preparing and reviewing the communication plan at the beginning of the project especially with the stakeholders by considering regular communication mainly reporting the updated information with each of project team, while 27% stated that it is the duty of document control to circulate the information and reports to the project team, it is not a major issue, as per “their confirmation”. Factor number 8, the necessity of BIM or visualized system, 75% of respondents confirmed that BIM or any digitalized system is very important and it helps project managers and the project team to check the design, interfaces, sections, openings, locations of ducts and other components in the project before construction start. It improve the process and eliminate the waste during the construction. Other 25% of respondents stated that they don't have this technology and they have no time or support from the management to obtain any training for this new technology. Workers can remember elements such as workflow, performance targets, and specific required actions if they visualize them [21].

## 7. Conclusion

This study revealed the benefits of lean construction technique in construction industry, where lean must be considered as **a technique in construction projects at** project manager's level to enhance and improve design and process efficiency, lean can be applied to any project in construction industry or in any production process. If lean mechanism is implemented correctly, it can create huge and big improvement in the efficiency of work process, time, quality, materials control and cost, and productivity of manpower in

construction projects. The cost can be reduced and controlled where added value of the invested money in projects can be observed. Reducing process variability will also increase customer satisfaction and decreases the volume of non-value-adding activities as stated by [22].

Lean methodology and techniques can eliminate the waste, the non-value added, and unnecessary component of any working process. The increased visualization lean tool is about communicating key information effectively to the workforce through posting various signs and labels around the construction site. This includes signs related to safety, schedule, and quality. This tool is like the lean manufacturing tool, visual controls, which is a continuous improvement activity that relates to the process control.

Lean construction is considered as a powerful tool to enhance productivity by reducing wastage. Lean construction techniques and mechanism are not implemented in gulf rejoin compared to other countries. One of important tools that support the implementation of lean construction in projects can be computer aided design, CAD; and building information modeling, BIM, visual inspection, health and safety program, preventive and predictive maintenance, continuous improvement, design of target value, implementation of total quality management, just-in-time approach, and the work environment.

The word lean has been used most often and it is associated with lean thinking, lean manufacturing, lean construction and lean production [23]. The technique can also be used during design development in special contracts like design-build contract in construction industry. Lean construction involves ways of designing production systems to minimize waste in materials, time, and human effort, with the aim of generating maximum cost-effective value [24]

## 8. Recommendation

Managing construction projects always requires special techniques, e.g. lean construction techniques is one of the best tools can be used to minimize the waste during design and construction. Managing construction waste is one of the most necessary management processes to achieve project objectives which makes the senior managers of construction projects to focus on this tool to identify and analyze all the waste to improve productivity of project resources, minimize time and accidents, improve reliability, improve quality and ensure client satisfaction with a confirmed added-value for the project. Clear guidelines can be developed by experts in this field to encourage the adoption of lean construction.

It is extremely important to use modelling and visualization techniques to improve design, planning and communication. Early planning can improve the work flow that will be focused on the achievable tasks and avoiding mistakes and duplicated efforts where activities that not adding values can be eliminated. Value management techniques and just in time product item can be planned to help in maintaining risk management techniques where last planner system can be considered as well.

It is recommended that researches can develop further studies to determine how lean construction tools/techniques can be applied to eliminate the different types of waste in the construction projects in gulf rejoin. In addition, further studies can be investigated to find out the barriers of adopting lean construction in construction firms.

## References

- [1] Benedict A., Charles N., Barriers to Lean Adoption for Construction Projects, The Pacific Journal of Science and Technology, P 153, Volume 20. Number 1. May 2019
- [2] Intergraph. Lean Construction: Technology Advances in Lean Construction. Intergraph Corporation: London, UK. 03/12 PPM-AU-0160AENG.2012, 1-16.
- [3] Chen, H. and R. Taylor. "Exploring the Impact of Lean Management on Innovation Capability." PICMET 2009 Proceedings. Portland, OR. Aug 2-6, 2009. 826-834.
- [4] Ayarkwa, J., K. Agyekum, E. Adinyira, and D. OseiAsibey. "Barriers to Successful Lean Construction in the Ghanaian Building Industry". Journal of Construction 2012a. 5(1): 3-11.
- [5] Ayarkwa, J., K. Agyekum, E. Adinyira, and D. OseiAsibey. "Perspectives for the Implementation of Lean Construction in the Ghanaian Construction Industry". Journal of Construction.2012b. 5(1): 24-29.
- [6] Bertelsen, S. and L. Koskela. "Construction beyond Lean: A new understanding of Construction Management". Proceedings of the 12th Annual Conference of the International Group for Lean Construction. 1-11.2004. Elsinore, Denmark.

- [7] Fapohunda, J.A. "Innovations towards Efficient Construction Resources Optimal Utilization in the Construction Industry-A Review". *Journal of Construction*. 2014 7(2): 51-60
- [8] Jamil G., Bo X., Sabrina F. "Lean Construction Implementations in KSA Construction industry" *Construction Economic and Building*. March 2017, Volume 17, No.1, P.62
- [9] Glenn B., Yong W., Jin W., "Road Map for lean Implementation at the project level", CII Research report 234-11, University of California, Berkeley, 2007 P.55
- [10] Howell, "Implementing lean construction: Reducing inflow variation" *Proc, Conference on lean construction*, Santiago, Chile, Sep.1994
- [11] Assaf, S.A. & Al-Hejji, S. 2006, 'Causes of Delay in Large Construction Projects', *International journal of project management*, vol. 24 no. 4, pp. 349-357, <https://doi.org/10.1016/j.ijproman.2005.11.010>
- [12] McCullough, D.G. 2014, Saudi Arabia Green Decree Brings Hopes of Sustainability. *The Guardian*, [online] Available at: <https://www.theguardian.com/sustainable-business/saudi-arabia-green-construction-oil-sustainability-environment>
- [13] AlSehaimi, A.O., Tzortzopoulos, P. & Koskela, L. Last Planner System: Experiences from Pilot Implementation in the Middle East, 2009
- [14] Fapohunda, J.A. "Innovations towards Efficient Construction Resources Optimal Utilization in the Construction Industry-A Review". *Journal of Construction*.2014, 7(2): 51-60.
- [15] Ogunbiyi, O. "Implementation of Lean Approach in Sustainable Construction: A Conceptual Framework". Doctoral Thesis. 2014. University of Central Lancashire: UK.
- [16] Opeoluwa A., Ayodeji O., Clinton A., "Benefits of Adopting Lean Construction Technique in the South African Construction Industry". *Proceedings of the International Conference on Industrial Engineering and Operations Management Pretoria / Johannesburg*, South Africa, p.1271,2018. October 2s9 – November 1.
- [17] Lehman, T. & Reiser, P. 2000, *Maximizing Value & Minimizing Waste: Value Engineering and Lean Construction*. New York: Lean Construction Institute
- [18] Howell, G.A., What is Lean Construction-1999. In: *Proceedings IGLC*, (7), p. 1
- [19] Forbes, L.H. & Ahmed, S.M. *Modern Construction: Lean Project Delivery and Integrated Practices*. Boca Raton, 2011, FL: CRC Press Inc
- [20] Koskela, L., Howell, G., Ballard, G., and Tommelein, I. "The Foundations of Lean Construction." *Design and Construction: Building in Value*, R. Best, and G. deValence, eds., 2002, Butterworth-Heinemann, Elsevier, and Oxford, UK.
- [21] Salem, O., Solomon, J., Genaidy, A., and M. Luegring. "Site Implementation and Assessment of Lean Construction Techniques". *Lean Construction Journal*, Lean Construction Institute, 2005, Vol 2, No. 2.
- [22] Koskela, L. "Application of the New Production Philosophy to Construction". *Technical Report # 72*, 1992, Center for Integrated Facility Engineering, Department of Civil Engineering, Stanford University, CA.
- [23] Ballard, G. and G. Howell. "What Kind of Production is Construction?" *Proceedings of the 6th Annual Conference of the International Group for Lean Construction*. IGCL: 1998, Guaruja.
- [24] Pinch, L. Lean Construction, *Construction Executive*, 2005. vol. 15 no. 11, pp. 8-11